An Overview of the CERC ARTEMIS Project

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The basic premise of this effort is that health care can be made more effective and affordable by applying modern computer technology to improve collaboration among diverse and distributed health care providers.

Information sharing, communication, and coordination are basic elements of any collaborative endeavor. In the health care domain, collaboration is characterized by cooperative activities by health care providers to deliver total and real-time care for their patients. Communication between providers and managed access to distributed patient records should enable health care providers to make informed decisions about their patients in a timely manner. With an effective medical information infrastructure in place, a patient will be able to visit any health care provider with access to the network, and the provider will be able to use relevant information from even the last episode of care in the patient record. Such a patient-centered perspective is in keeping with the real mission of health care providers.

Today, an easy-to-use, integrated health care network is not in place in any community, even though current technology makes such a network possible. Large health care systems have deployed partial and disparate systems that address different elements of collaboration. But these islands of automation have not been integrated to facilitate cooperation among health care providers in large communities or nationally.

CERC and its team members at Valley Health Systems, Inc., St. Marys Hospital and Cabell Huntington Hospital form a consortium committed to improving collaboration among the diverse and distributed providers in the health care arena. As the first contract recipient of the multi-agency High Performance Computing and Communications (HPCC) Initiative, this team of computer system developers, practicing rural physicians, community care groups, health care researchers, and tertiary care providers are using research prototypes and commercial off-the-shelf technologies to develop an open collaboration environment for the health care domain. This environment is called ARTEMIS -- Advanced Research TEstbed for Medical InformaticS.

INTRODUCTION

ARTEMIS leverages existing CERC-developed technology as well as the concurrent engineering approach of involving the customer from the onset of the project. ARTEMIS will be field-validated at participating sites in southern West Virginia [1]. Our team will deploy a set of software systems in a growing number of health care facilities, in a phased manner, and will demonstrate:

- physicians treating patients using patient records and other knowledge from distributed sources;

- primary care physicians consulting with remote specialists in the areas of perinatology and radiology, facilitated with computer support for X-rays, ultrasound, voice annotations, and other multimedia information; and

- primary care and specialized care providers collaborating via a community care network to meet a community's health care needs.

The team will also measure the system's effectiveness in reducing health care costs. In addition, they will focus special attention on issues related to quality assurance, privacy, confidentiality, and data integrity.

This paper presents an overview of the features supported by ARTEMIS and the software architecture that has been used in the development of ARTEMIS.
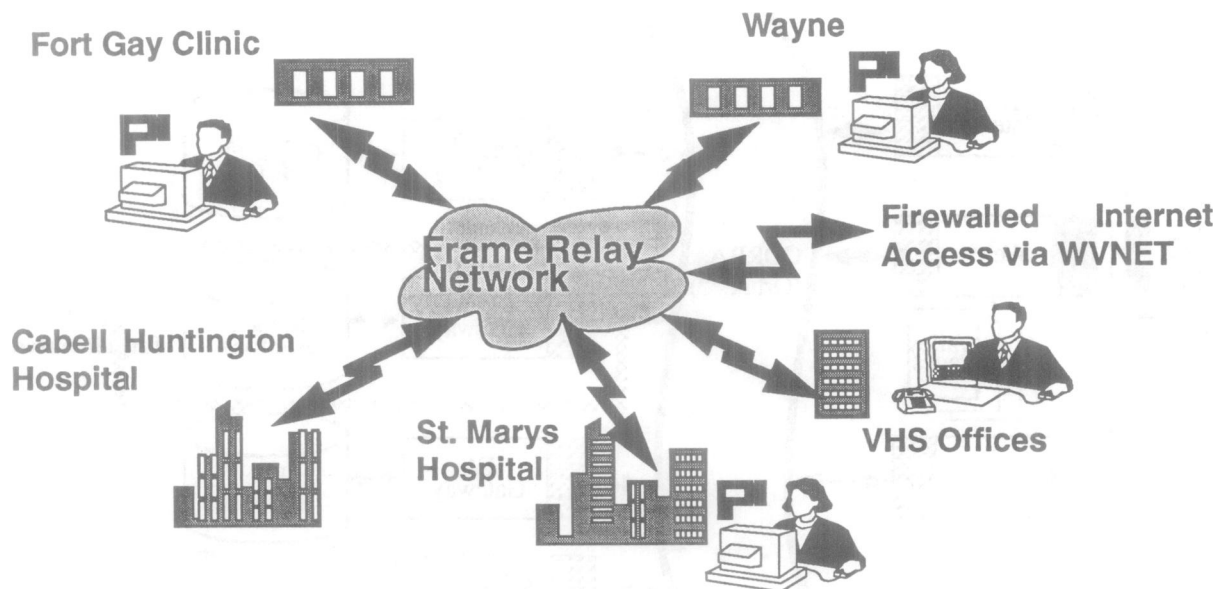
Figure 1. Current configuration of ARTEMIS testbed

FEATURES OF THE ARTEMIS SYSTEM

The ARTEMIS system is being designed to support a variety of collaborative transactions among the health-care providers at Valley Health Systems, St. Marys Hospital and Cabell Huntington Hospital.

Remote Consultation Features:

- Physicians can engage in face-to-face consultations with specialists using a desktop teleconference consultation system over the network.

- Nurse practitioners can consult with physicians in the same manner.

- During consultations, participants can share patient information, such as X-rays, and can point to and mark such information in a "what-you-see-is-what-I-see" mode.

Features for the Electronic Access of Patient Records:

- secure electronic access to the multi-media patient record using the World Wide Web based, hyper-text document metaphor;

- access to information from anywhere, including provider homes, using standard, off-the-shelf Internet browsing tools on PCs;

- Oracle-based patient record storing;

- a multi-media file archiver for voice, images such as X-rays, and scanned documents;

- support for the Health Level 7 (HL7) standard.

Collaborative process support features:

- dictation process support, allowing the capture of dictation and support for the transcriptionist;

- support for referrals and consultations: providers can send multi-media mail to other providers, attaching relevant portions of the patient record;

- support for faxing, printing, and mailing any portion of the patient record to anyone;

- notification of reports to be signed or co-signed (in the case of nurse practitioners); and

- visual feedback on which correspondence has been answered and which has not.

Infrastructure features:

- a Community Care Network involving four sites;

- frame relay connectivity;

- firewalls to protect access to the Community Care Network from outside

TECHNOLOGICAL UNDERPINNINGS OF ARTEMIS

An initial implementation of the ARTEMIS environment has been completed, with the following distinguishing features:

- adoption of the Hyper-Text Transfer Protocol [2] (HTTP) protocol for client-end interoperability;
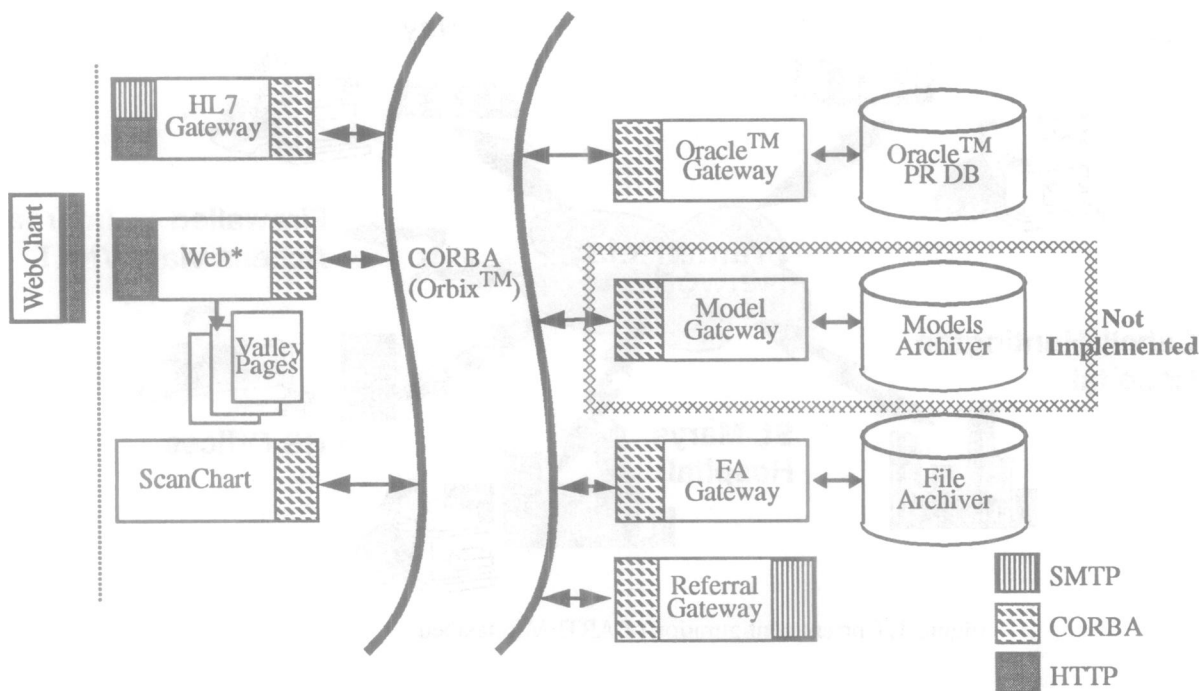
Figure 2. ARTEMIS Patient Record Environment

- adoption of the Common Object Request Broker Architecture [3] (CORBA) specifications for server-end interoperability using Orbix^{TM};

- use of the CERC-developed Web* software to bridge HTTP and CORBA environments;

- gateways to a commercial relational database (Oracle^{TM});

- adoption of the Kerberos standard for authentication;

- model-based, wide-area access to patient records, with the capability to update structured and unstructured information;

- federated access control mechanisms (the information provider decides who can access the information);

- adoption of the hyper-text document metaphor (Mosaic) to support ease of use;

- desktop conferencing among healthcare providers using the CERC-developed MONET teleconference system;

- synchronous information sharing for patient information and images, such as X-rays; and

- notification and asynchronous communication, based on MIME-compliant multi-media mail, for ordering laboratory tests and referrals.

This version of the system is currently being tested for a formal field trial by health care providers and is expected to be in experimental use at two clinics (Fort Gay and Wayne Clinics) within Valley Health Systems, at St. Marys Hospital and at Cabell Huntington Hospital by Fall 1995.

ARTEMIS ARCHITECTURE

Figure 2 shows the architecture of ARTEMIS environment dealing with Patient records. We will give a brief overview of each of the above components and the technology that it leverages below.

WebChart

This module is a customized World-Wide-Web (Web, for short) browser that allows simultaneous display up to four-pages of patient record. Providers can use off-the-shelf commercial web browsers for examining patient information at home or from remote locations. But it was felt that for efficient operation within a clinic, where the provider has very little time to navigate multiple hyper-links it is important that as much information about the patient (customized to the needs of the provider and based on patient characteristics) should be presented in one screen. This is what Web-Chart does. This module also supports: sign-offs, dictation, referrals, printouts, and faxing of patient information.

Web*[4]

This module developed as part of the ARTEMIS system is a generic module that can be used in any domain

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- not just in health care. This module bridges the two different protocols - the stateless HTTP protocol and the state-full CORBA environments.

The main functionality provided by this module is to extract information from distributed information sources, such as Oracle, and to dynamically construct pages in Hyper-Text Markup Language (HTML) which can be retrieved and presented using commercial and publicly available Web browsers.

HL7 Gateway [5]
There is a prototype version of an HL7 gateway that allows the query-and-retrieval of a subset of HL7 messages. The implementation of this prototype allows for person to send HL7 query message over electronic mail and to receive the results of the query in email as well. An alternative interface, allows for specifying such query using Mosaic-forms using the Web. Currently the set of messages supported are those that involve patient records that are typically available in small clinics. Currently the system does not support the parsing of arbitrary HL7 messages and storing the same in databases. It supports specific update messages.

ScanChart
This is a module which allows for the scanning of paper documents and linking it with the patient chart. We are currently experimenting with multiple interfaces for this as well. There is a motif-based interface that interfaces and uses Orbix objects. We also have a simpler version that works off a Web-browser. The Web version is being tested at Valley Health Clinics on usability and performance.

Oracle Gateway
This is a generic gateway to Oracle implemented using Orbix encapsulation capabilities. This gateway provides support for opening databases, supporting Structured Query Language (SQL), and accessing various transactions such as commit and rollback. This module also manges time-out, concurrency control and can provide (though not currently implemented) for logging and audit trails.

Oracle Patient Record Database
This module implements the patient record for Valley. There are roughly 72 relations and over 1000 patient attributes. The relations are normalized and support for an evolutionary expansion of the model. The database design also includes access control mechanisms, sign-off mechanisms and is used to track referrals.

File Archiver
The File Archiver has also been implemented using Oracle. This is simply a mechanism to index arbitrary files and link it to the patient chart. The files could be audio, video clip, scanned documents, images or whatever needs to be linked in an organized manner to the patient chart. In addition, this module supports both CORBA and HTTP protocols and hence allows for files to be submitted in multiple modes. The initial experimental version put in Valley does not at this point support the submission of files from geographically different location.

Valley Pages
These set of layout-pages are Valley Health System (VHS) specific. This module captures as HTML-templates all the forms that Valley has in Prenatal and General practice. These pages implement the view seen by all Web clients and can be customized to provide process support for sign-offs and referrals. This module also supports some limited mechanisms by which providers can customize their own view of the patient chart.

Referral Gateways
This module is currently not completed. When completed it will package select patient information - on providers request - and send it as a secured multimedia mail package to the referred provider. Several prototype versions of this gateway exists and effort is currently underway to test and integrate results from a number of these prototypes.

Model Gateway and Model Archiver
This module is not implemented at this point. It is viewed as a generic object-oriented model of the patient record that will make the task of creating the layout pages significantly easy.

SECURITY ISSUES

The Community Care Network that has been created at Valley has been fire-walled to prevent access from the outside world. Valley's HTTP-servers will not be accessible from outside. They will be accessible through a dedicated ISDN-line in the experimental phase to select providers from their homes.

Standard password protection and access control mechanisms have also been implemented. The next release of the system will also use commercial off-the-shelf secure-http protocols.

Referrals based on multi-media mail will use public-key-private-key encryption mechanisms.

PERFORMANCE ISSUES

Initial testing at VHS has shown that performance is critical in clinic settings for a successful use of the system in routine care. Currently performance tuning is underway including mechanisms such as caching and pre-fetching. Performance is not that critical in a home setting where the emphasis is more on availability and access to information. The Web-approach makes it straight forward to provide such access using standard PCs and commercial off-the-shelf Web-browsers.

Experimental trials using the system is scheduled to begin in Fall '95 and currently the system is undergoing rigorous testing.

EVALUATION OF THE ARTEMIS SYSTEM

We intend to evaluate the impact of the ARTEMIS system by examining various factors before and after the phased deployment of the Community Care Network at the demonstration sites. Factors to be considered include the amount of effort required of the provider to use the patient records; the amount of missing information; reduction of duplicate testing; assistance in quality assurance efforts; usefulness of new features provided by the Community Care Network, such as packaging material for referral and consultation; access to images across the network; and the graphical display of data. Initially, prenatal care providers will be studied; later phases of the evaluation will cover all other types of providers.

Our approach for conducting this study incorporates multiple strategies, including:

- the use of questionnaires, work sampling methods, and time motion studies;

- the use of a unique model being developed at CERC called the Provider Utilization and System Effectiveness (PULSE) model, which is based on the "Kiviat" graph in the simulation domain; and

- the simulation of the ARTEMIS Community Care Network (at Brown University) to examine issues of scale-up, the optimal configuration of system resources, opportunities for process improvement, and the performance/economics of deploying a wide scale Community Care Network.

CONCLUSION

The ARTEMIS system is scheduled for experimental testing in a clinical environment in spring of 95. The design and development efforts for developing this system used a rapid-prototyping approach and a concurrent engineering philosophy of putting the customer - in our case, the providers - a part of our design team. The development leverages collaboration technology, which has been the focal point of research at CERC for over six years, and advances in internet and integration technologies which are emerging currently.

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